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14. ABSTRACT

Our laboratory has been working towards completion of an adaptive clustering spike-sorting circuit and the acquisition of bat vocalizations from a flying bat. In this summary for the project, we show some basic operation of the spike-sorting chip and discuss issues for further development. We have successfully flown a radio telemetry microphone on a bat and recorded good signals for the beginning of a new series of bat behavioral experiments.

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Spike sorting circuits, bat echolocation, biologically-inspired algorithms & electronic circuits, radio telemetry

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Final Report for AFOSR (Grant # FA95500410188)
"Spike-sorting at the Electrode"

Timothy K Horiuchi, University of Maryland, College Park
(August 2006)

Our laboratory has been working towards completion of an adaptive clustering spike-sorting circuit and the acquisition of bat vocalizations from a flying bat. We have run into problems with our spike-sorting chip and are resubmitting a new design that should resolve some of the problems. The microphone telemetry project is moving forward with a functioning receiver system (which is a modified commercial product) and we are finalizing our first microphone transmitter design for testing with a bat in the next month or two.

1. The Adaptive-Clustering Spike-Sorting Chip

The previous report described the design of a spike-sorting chip that uses a 3D feature clustering algorithm along with a pulse-width limiting circuit that rejects narrow glitches and wide pulses. After receiving the chip back, we began testing and characterization.

Initial testing has revealed a few problems with the trough feature detector and we have been reworking the chip design to correct the problem. Our chip design is still in process as other parts of the project are pushed forward.

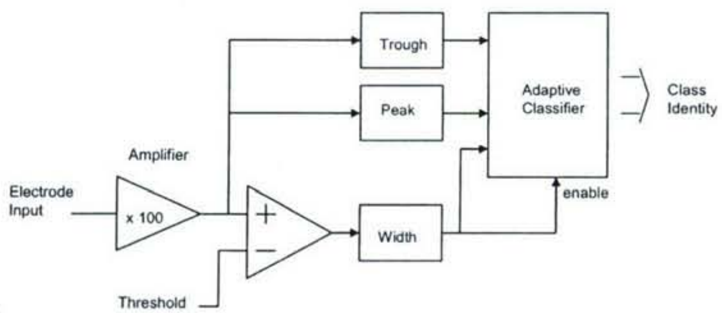
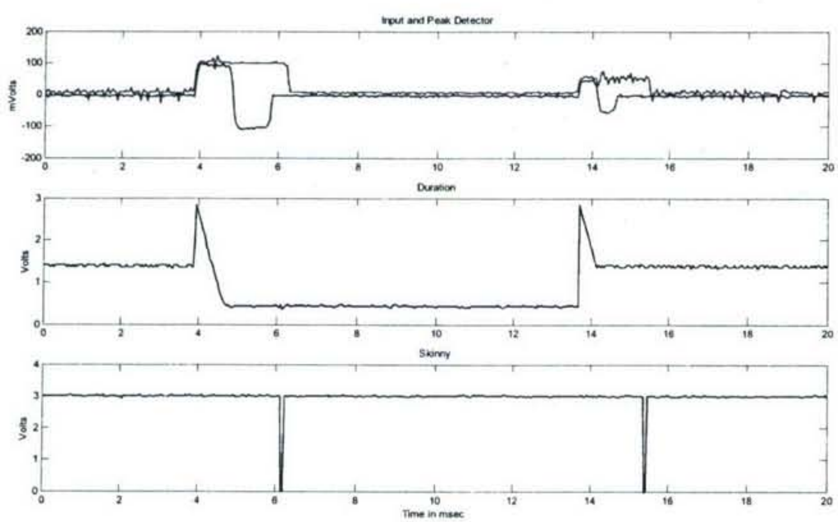
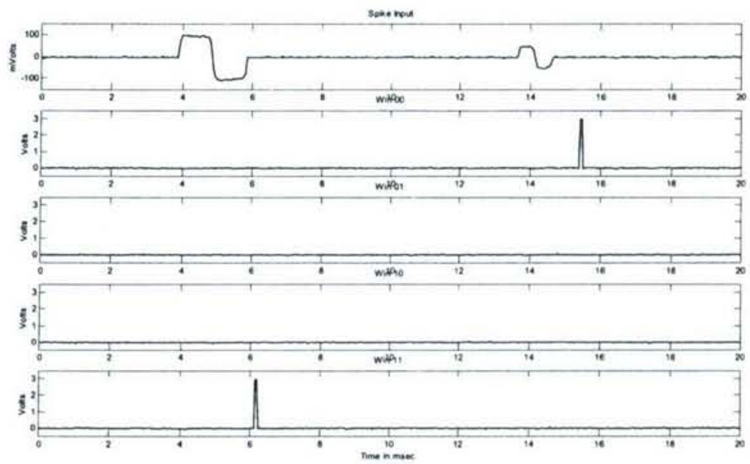


Figure 1. Our current plan for the automatic detection and classification of spikes consists of an amplifier, threshold comparator, feature detectors and a multidimensional clustering classifier. The initial adaptive classifier chip will be based on a radial basis function approach.

We are attempting to construct a work-around that will allow us to test the remainder of the adaptive system without the trough detector, effectively using only two of the three (width and peak) dimensions.



In the figure above, the upper trace shows (blue) a simulated input spike waveform and the (red) peak detector circuit reporting the peak voltage for a short time afterwards. The middle panel shows the duration ("width") circuit using a triangular ramp circuit to report the duration of the spike as a voltage. The lower panels shows the "valid" signal indicating that the duration was within the upper and lower limits of "valid" pulse widths.



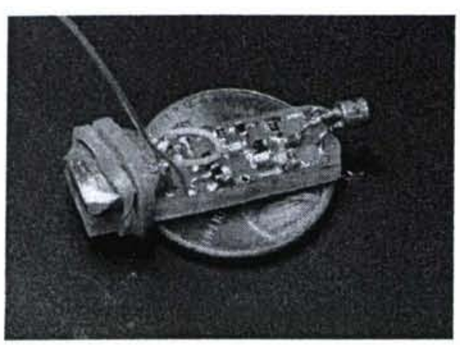
In the figure above, the upper-most trace shows a successfully learned classification based on a combination of duration and peak voltage. The second through fifth panel shows the binary output of four detector circuits indicating the detection of spikes from classes #4 and then #1.

While the basic architecture is functional and operates basically as expected, we are redesigning the trough detector and addressing some capacitor leakage problems related to memory retention of the classification parameters.

2. *Development of the Ultrasonic Microphone Transmission System*

In parallel to the work described above, a graduate student (Nayef Ahmar) in 2005 worked on the adaptation of a commercially-available radio receiver for collecting data in our ultrasonic microphone telemetry system. To collect vocalization data from the flying bat, a very simple and light (~2 gm) microphone telemetry system is being developed. By using a very simple circuit design and relatively low carrier frequencies (141 MHz), the device can be made quite small. There are several difficulties in this design: 1) low carrier frequencies are inefficiently transmitted from small antennas, and 2) simple FM transmitters based on RLC (passive resistor, capacitor, and inductors) time constants suffer from drifting carrier frequencies due to temperature changes and changes due to parasitic coupling. While the inefficient coupling can be overcome with large and well-placed receiving antennas, drifting carrier frequencies requires a receiver that can keep pace. While most radio receivers do contain an automatic frequency tracking control (AFC), they are always limited in how far signals are allowed to drift. An additional difficulty is obtaining a receiver that can demodulate FM signals operated at rates as high or higher than 80kHz.

To deal with this problem, we purchased a system that is well known by hobbyists and information regarding internal points on the printed circuit board is available. This software-controlled radio receiver (iCOM PCR1000) allows us to change the center frequency through the serial port and allows the upload of a spectral analysis performed on the signal inside the receiver. By using a low-sampling rate control loop to keep our center frequency in the middle of the spectrum, we would be able to track a transmission if were to drift across the entire frequency range of the radio.

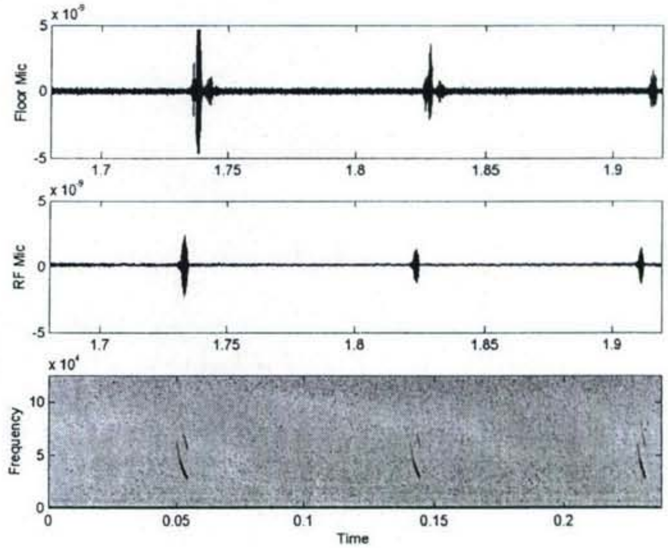


We have also taken a signal from the middle of the printed circuit board that is the raw, unfiltered envelope output signal from the demodulator circuit, prior to audio frequency filtering and amplification.

As part of this work, we have experimented with other transmitter designs, such as with a surface acoustic wave device that provides a very stable carrier frequency, but is not very easily used for FM transmissions. These devices with such high quality factors also tend to have slow temporal response.

This transmitter currently weighs 1.8 gm including the battery and has a range of approximately 40 feet, however, some radio interference occurs sporadically, but does not incapacitate the system. Through other support (not AFOSR) which covers animal experiments and efforts with Prof. Moss' laboratory we have begun recording from the bat in flight. We have now begun various coordinated experiments with simultaneous 3D video reconstructions and microphone array recordings.

The top recording is from a microphone placed on the floor of the flight room. This recording shows clipping and significant echo reception as the vocalization reflects off of various surfaces. The middle recording comes from our telemetry system mounted on the head of the bat. The gain is significantly lower but records the louder signal well. Reflections are not visible. The bottom panel shows the spectrogram of the telemetry system verifying that the signals visible are, in fact, bat vocalizations with their signature chirp pattern.



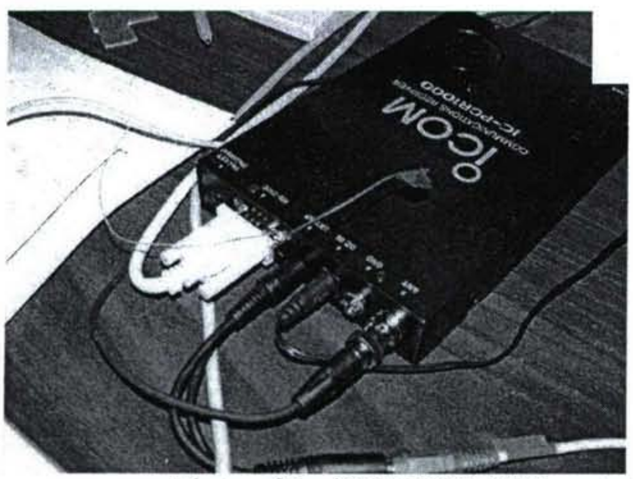


Photo of the iCOM PCR-1000 controlled by a PC through the serial port connection.

Data recording of the receiver output is handled by the data acquisition systems used by the Moss laboratory for their other fixed microphone recordings.

This telemetry system is being modified for use in collaborative work with investigators studying ultrasonic mouse vocalizations.